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ZONAL WEATHERING OF A HORNBLENDE GABBRO

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In connection with a study of the alteration of the so-called trap or diabase dikes at La Grange, Georgia,¹ one of the writers collected some interesting specimens showing a weathered zone in which the decomposition is extreme, with an abrupt transition into fresh rock, practically free from the effects of weathering. This paper is concerned with the description of a typical specimen, and with the results of chemical analyses of the fresh rock, the partly altered material, and the extreme phase of alteration present.

La Grange is in the extreme western edge of the state, not many miles from the southern end of the belt of crystalline rocks which extends from Maine to Alabama. The country rock is for the most part gneiss, cut by granitic intrusions. Both gneiss and granite are cut by pegmatites and basic dikes, the latter usually called diabase, and supposed to be of Triassic age. At La Grange there is a series of dikes, only a few feet apart, ranging up to forty feet in width, with an average of about four to six feet. The dikes have a general north-south trend, and are abundant over an area of a little more than half a square mile.

The older crystalline rocks are very deeply weathered. The basic dikes have been considerably altered at the surface, and in many instances may be traced by the strong iron stain they have imparted to the soil. In some excavations, however, material showing no appreciable effects of weathering may be obtained. In some cases weathering has been strongly marked along joints, changing the character of the material for an inch or less, beyond which the rock is fresh. Fig. 1 shows a specimen in which the zone of alteration is about an inch thick. Analyses were made of the

¹ L. P. Smith, *Alteration of Diorite by Weathering*, Dissertation, University of Chicago, 1915.

outside, much-altered portion, and of the part of the weathered zone adjacent to the fresh material. A specimen from an entirely fresh portion of the same dike was analyzed for a comparative study.

The fresh rock is finely grained, holocrystalline, nearly black in color, with small white feldspar crystals evenly distributed through



FIG. 1.—Specimen showing zone of weathering $\times \frac{1}{2}$. Circle shows approximately the part from which the slide shown in Fig. 3 was taken.

the mass, which is dominantly hornblende. Small garnets, irregularly distributed, and small crystals of pyrite are present. Microscopically, the rock is found to consist of hornblende (65 per cent), which may be secondary, labradorite (32 per cent), with small amounts of orthoclase and augite, and accessory magnetite, pyrite, titanite, and apatite. One of the typical slides is shown in Fig. 2. The rock is a hornblende gabbro.

The partly altered material is notably lighter in color than the fresh rock. Most of the hornblende has been weathered, leaving brown iron stains and a small amount of chlorite, but some particles of apparently fresh hornblende are to be seen. The feldspar has been changed to a chalky white material in an iron-stained matrix. Microscopical study reveals some unchanged hornblende, but for the most part only alteration products are discernible. Limonite, white mica (probably also gibbsite),

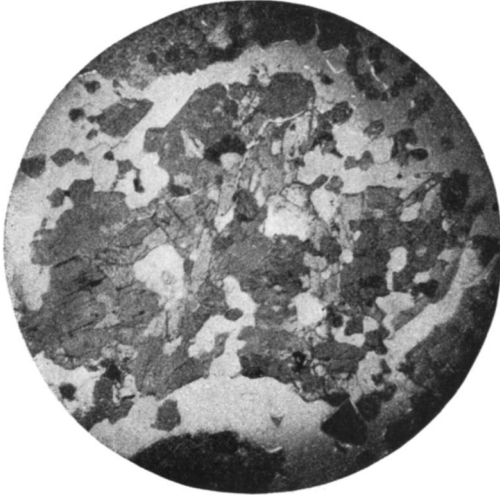


FIG. 2.—Section of fresh hornblende gabbro $\times 20$. (Two rather large cracks appear as light bands.) Ordinary light.

chlorite, zoisite, and a small quantity of magnetite make up the mass. The weathered zone is sharply set off from the fresh material even in thin section. In Fig. 3 the fresh portion is shown on the left, changing to altered on the right.

The most completely weathered portion is a friable, earthy, non-plastic mass, strongly iron stained, and so thoroughly disintegrated that the original texture of the



FIG. 3.—Slide showing transition from fresh to altered portion of specimen. $\times 25$. Crossed nicols.

rock is practically lost. No microscopical study of this material was undertaken.

The results of chemical analyses, made in duplicate in every case and in triplicate in a number of determinations, are given in Table I. The following recognized effects of weathering are well illustrated: loss of silica, apparent increase in alumina, increase in ferric iron, decrease in ferrous iron, loss of bases, increase of combined water, and decrease in specific gravity. The very small development of carbonates may be due to the fact that most of the available carbon dioxide has formed soluble bicarbonates in removing lime, magnesia, and alkalis.¹

TABLE I

	1*	2†	3‡		1*	2†	3‡
SiO ₂	45.16	26.02	23.34	TiO ₂.....	.31	.18	.15
Al ₂ O ₃	17.52	28.60	32.70	MnO.....	.47	.51	tr.
Fe ₂ O ₃	3.12	11.38	21.77	CO ₂	none	.12	.52
FeO.....	6.99	4.00	none	S.....	.10	.04	none
MgO.....	4.67	3.03	.57	Total.....	100.10	100.23	100.20
CaO.....	17.50	7.96	.75	Total Fe.....	7.62	11.78	15.24
Na ₂ O.....	2.39	1.54	.39	Sp. Gr.§.....	3.020	2.813	2.340
K ₂ O.....	1.37	.81	1.19				
H ₂ O-.....	.04	.87	3.77				
H ₂ O+.....	.46	15.17	15.05				

* Fresh Rock.

† Altered near the fresh rock.

‡ Altered, most decomposed portion.

§ Pycnometer method.

On the assumption of constancy of alumina² the analyses may be recalculated, and gains and losses estimated, as shown in Table II. The change in total iron is worthy of note, in that there is a slight loss shown in 2, with a marked increase in 3. A suggested explanation is that during the early stages of alteration some soluble ferrous compound was formed, which migrated, perhaps by capillary action, to the outer zone before it was precipitated by oxidation to

¹ In this connection it may be noted that wells in or near the dikes are said to yield water containing considerable amounts of lime, while those in the gneiss, farther from the dikes, yield comparatively soft water. Unfortunately, no quantitative data on these waters are available.

² G. P. Merrill, *Rocks, Rock Weathering and Soils*, p. 208.

the ferric condition. That the removal of ferrous iron may take place in the early stages of alteration has been commonly recognized.¹

TABLE II

	1	2	Gain	Loss	3	Gain	Loss
SiO ₂	45.16	15.94	.....	29.22	12.51	.....	32.65
Al ₂ O ₃	17.52	17.52	.....	.....	17.52	.....	.....
Fe ₂ O ₃	3.12	6.97	3.85	.....	11.66	8.54	.....
FeO.....	6.99	2.45	.....	4.54	none	.....	6.99
MgO.....	4.67	1.86	.....	2.81	.31	.....	4.36
CaO.....	17.50	4.87	.....	12.63	.34	.....	17.16
Na ₂ O.....	2.39	.94	.....	1.45	.21	.....	2.18
K ₂ O.....	1.37	.50	.....	.87	.64	.....	.73
H ₂ O—.....	.04	.53	.49	.....	2.36	2.32	.....
H ₂ O+.....	.46	9.29	8.83	.....	8.06	7.60	.....
TiO ₂.....	.31	.11	.....	.20	.08	.....	.23
MnO.....	.47	.31	.....	.16	tr.	.....	.47
CO ₂	none	.07	.07	.....	.28	.28	.....
S.....	.10	.02	.....	.08	none	.....	.10
Total.....	100.10	61.39	.....	.....	53.95	.....	.....
Total Fe.....	7.62	7.21	.....	4.05	9.33	1.71	.....

Essentially the same relations are shown by the "straight line" diagrams of Mead.² In Fig. 4 the analyses of the altered portion are compared with that of the fresh rock. The full line represents analysis 2, and the broken line analysis 3. In general, 3 is merely an accentuation of 2, except for potash and total iron, both of which show a change of sign in the direction of change. It is apparent that in the later stage of alteration the removal of bases continues, and that it is out of proportion to the further removal of silica as compared with 2. The retention of potash is by no means unusual.

In Table III the analyses are recast to molecular proportions to emphasize some of the chemical and mineralogical features. It is to be noted that even in analysis 2 the amount of silica is insufficient to combine with all of the alumina to form kaolin. The alumina : silica ratios are as follows: 1, 1:4.36; 2, 1:1.57; 3, 1:1.19. For kaolin 1:2 is required. On the extreme assumption that all of the silica in 3 is present in the form of kaolin, the analysis may be said to

¹ C. K. Leith and W. J. Mead, *Metamorphic Geology*, p. 22, Henry Holt & Co. (1915).

² W. J. Mead, *Econ. Geol.*, VII (1912), 141-44.

represent (by weight) kaolin, 50 per cent; limonite, 25 per cent; bauxite, 18 per cent; other substances, 7 per cent. It is highly probable that part of the silica is present in some compound not containing alumina, and if so the amount of bauxite is correspondingly greater. This lends a distinctly bauxitic-lateritic aspect to the alteration.

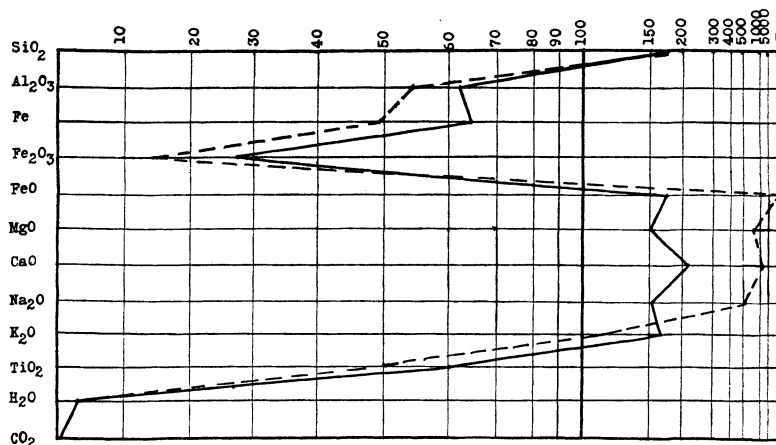


FIG. 4.—“Straight line diagram” showing changes in composition with alteration. The full line represents analysis 2, the broken line analysis 3, compared with the analysis of the fresh rock.

TABLE III
Per cent ÷ mol. wt.

	1	2	3		1	2	3
SiO ₂ . . . . .	.747	.431	.387	CaO . . . . .	.312	.142	.013
Al ₂ O ₃ . . . . .	.172	.280	.320	Na ₂ O . . . . .	.039	.025	.006
Fe ₂ O ₃ . . . . .	.020	.070	.136	K ₂ O . . . . .	.015	.008	.013
FeO . . . . .	.097	.056	.000	H ₂ O+ . . . . .	.026	.845	.836
MgO . . . . .	.116	.075	.014	CO ₂ . . . . .	.000	.003	.012

Specimens similar to the one studied are not uncommon in the weathered part of the dikes, and the changes shown are believed to be fairly typical for the rock in question. It is to be noted that the fresh rock is much richer in iron than rocks which yield bauxite deposits, and richer in alumina than those yielding high grade laterite deposits.